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VIII.

BRIEF CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF HARVARD COLLEGE.

No. I.

ON THE EFFECT OF HEAT UPON THE MAGNETIC SUSCEPTIBILITY OF SOFT IRON.

By H. Amory and F. Minot.

Presented, Jan. 12, 1875.

The determination of the question whether heat influences the capabilities of soft iron to be magnetized appears to us to be an interesting question, since, in the later forms of magneto-electric engines, the armatures necessarily become heated by their movement in a magnetic field. The question is also of interest from a molecular point of view. We have confined ourselves to the determination of the effect of such heating upon the induced currents produced by suddenly passing an electric current about the bar of soft iron, which is heated to different temperatures.

Great difficulty was anticipated at first in determining the temperatures of the bar at different times. Preliminary experiments show, however, that the question resolved itself into observing the decided changes at the temperature of dull red heat and at white heat. The first method of experimenting was as follows: bars of soft iron, 1 cm. in diameter, were placed so as to form the armatures of the electro-magnets; a coil of fine wire, the induction coil, was slipped upon these bars, forming the armatures, and the curve was drawn, which showed the distribution of magnetism over the armature when the electro-magnets were excited; then the bar was heated, and the change in the curve noted. The induction coil was so placed that its plane was at right angles to that of the coils of the exciting electro-magnets. This apparatus showed a slight increase of magnetic susceptibility in the bars of soft iron as they were heated. The magnetic state increased up to the point when the bar began to change slightly in color from the effect of the heat; it then remained constant. Owing to the difficulty of heating bars of comparatively large diameter to a point beyond that of dull red heat, this method was abandoned, and the following was adopted. The testing apparatus consisted of an electro-magnet, horseshoe in form, but the wire of which was placed at the bend of the horseshoe, so that the electro-magnet was practically a straight one, with a horseshoe-shaped core. Upon one of the limbs of the horseshoe the induction coil was slipped, so as to still remain at right angles with the electro-magnet. The soft iron bar or wire was then made the armature of the electro-magnet. It was found that this arrangement was a very sensitive one; for any change in the condition of the wire forming the armature was immediately shown when the electro-magnet was excited, and an induced current passed through the fine induction coil. This method allowed us to experiment with wires, or bars of any suitable diameter. For, as it will be shown later, the size of the armature had very little effect upon the strength of the induced currents produced at making and breaking the current in the electro-magnet. We shall speak of the horseshoe-shaped core and the armature as a magnetic circuit, which of course is a mere convenient term. When the armature is applied to the poles of the horseshoe, and the electro-magnet is excited, then such a circuit may be said to be closed. The bars or wires were tested at a dull red heat, and also at white heat. The first bar used was 2 mm. in diameter, and the following table shows the results obtained. Six observations were taken, at intervals of one minute apart.

TABLE I.

Time.	Deflection of Galv. Needle before heating.	Deflection of Galv. Needle on rise of temperature.	
Min.		Dull Red.	White Heat.
1	58	59	52
2	57	58	53
3	57	59	52
4	56	59	52
5	56	59	52
6	56	58	52

When the magnetic circuit was closed by the armature, the first induced current which was produced by making the circuit of the electro-magnet was greater than the succeeding ones. This was doubtless due to residual magnetism. We do not speak of the induced current which resulted from breaking the circuit of the electro-magnet; for this was equal to that produced by making the circuit. The mean of the two renderings gave the correct result.

The following show the results obtained by varying the size of the bars or wires forming the armatures: —

TABLE II. — DIAMETER OF BAR, 2.5 MM.

Time.	Deflection of Galv. Needle before heating.	Deflection of Galv. Needle on rise of temperature.	
Min.		Dull Red.	White Heat.
1	59	60	52
2	58	59	53
3	57	60	50
4	57	58	52
5	57	59	52
6	56	60	52

TABLE III. — DIAMETER OF BAR, 3 MM.

Time.	Deflection of Galv. Needle before heating.	Deflection of Galv. Needle on rise of temperature.	
Min.		Dull Red.	White Heat.
1	58	61	52
2	56	59	50
3	57	60	51
4	56	59	53
5	57	59	52
6	56	60	50

Bars of various small diameters were used with results corresponding to those given in the above tables. It was evident that the size of the armature had very little effect upon the induced magnetism, or upon our testing induced currents. To determine this point, we made a series of determinations of the strength of the induced currents which resulted from the employment of armatures of various sizes. The results are contained in the following table: —

Weight of Armature in grammes.	Deflection of Galvanometer Needle.
470	150
340	151
200	148
100	.150

This fact has an important bearing upon the practical construction of magneto-electric engines; for it seems that we can vary the size of magnetic revolving armatures, within large limits, to suit considerations of speed, &c., without affecting materially the induced currents, through coils upon the limbs of horseshoe magnets, near the poles of which the armature revolves. The above tables show that there is a slight increase of magnetism as the bar heats. Preliminary tests showed that the increase was slow, but gradual, up to the temperature of dull red heat; then, as the bar was heated to the temperature of white heat, its magnetic susceptibility fell, and apparently became less as the temperature increased beyond that of white heat. On cooling, the bar quickly regained its normal magnetic state of susceptibility. Thus, the curve which represents such a change would rise nearly as a straight line, inclined to the axis of X at a slight angle, up to the point of dull red heat; then it would fall quickly, in nearly a straight line, to the point of white heat; rising quickly again to the point of dull red heat, forming a V-shaped inflection in the curve, and then falling again, in nearly a straight line, towards the axis of X. One of Thomson's reflecting galvanometers was used in the above experiments. The results of the above show that the heating of the armatures of a magneto-electric engine increases rather than diminishes its magnetic susceptibility.